APPENDIX H

Geotechnical Analysis

MEMORANDUM

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SUBJECT: Western Alaska Access Project, Geologic Conditions

DATE: December 4, 2009

INTRODUCTION

This memorandum is intended to provide planning level information regarding suspected geologic conditions and hazards associated with each of the proposed road routes. The information also provides a general discussion about locations of materials that may be suitable for road construction. It is important to understand that the information presented below is based on surficial geologic maps and no fieldwork was performed. Soil conditions will vary over short distances along these corridors. As the project moves forward, additional information will be required in order to obtain a more accurate depiction of the area.

DEPOSIT DESCRIPTIONS

The following are unit descriptions for materials that are expected to be encountered along each of the proposed road routes and list their suitability for construction. The units are composed of the generalized material types listed on Figure H1, Generalized Geology Map.

Glacial Moraine and Drift: Also referred to as lightly modified moraine, moderately modified moraine, and highly modified moraine. Predominantly glacial till consisting of a mix of sand, gravel, silt, and clay, with cobbles and boulders. These deposits tend to be dense and can be constructed upon, but depending on the quantity of silts and clays present, may not be ideal for use as road construction material. Till is generally moderately to highly frost susceptible.

Glacio-lacustrine: Also referred to as proglacial lake and proglacial lake over moraine deposits. Glacio-lacustrine deposits are formed when melt water streams carrying suspended material flow into lakes bordering a glacier. These materials are usually composed of silts and sands but can include cobbles and gravels and are typically overlain by peat deposits. Glacio-lacustrine materials generally contain high silt percentages, are frost susceptible, and are not suitable for road construction.

Glaciofluvial: Also referred to as current glacial outwash and old glacial outwash. These deposits tend to consist of more sands and gravels than observed in glacial till. Glaciofluvial deposits are moderately to well sorted cobbles, gravels and sands with some silt deposited in active stream channels, floodplains, and usually associated with low terraces. Glaciofluvial deposits tend to be dense and can be constructed upon. Areas containing high silt concentrations generally are not suitable for road construction due to high frost susceptibility, moisture sensitivity, and difficulty in obtaining compaction.

Alluvial: Also referred to as fluvial, floodplain, alluvial terrace, alluvial fan, coarse & fine rubble, fine rubble, and alluvium over old alluvium. These deposits consist of modern floodplain, alluvial fan, and terrace deposits bordering major streams and rivers. The material is variable and ranges from gravels and sands with low silt content to extensive silt deposits. In streams and rivers, sands and gravels are typically deposited on the outside, or cut banks, of stream curves while silts are deposited in the broad, shallow sections of stream curves where water flow is slower. Sands and gravels make good building materials. Where the silt percentages are too low, silt can be added as a binder. Alluvial silt deposits are not suitable material for road construction as they are typically too wet to compact and highly susceptible to frost heave in winter.

Eolian: Also referred to as sand dune, upland loess, valley loess, and alluvium. Eolian deposits are comprised of fine-grained sediments (sand, silt, clay) deposited by wind. Eolian activity may result in deep silt deposits, usually located between stream valleys, as well as active sand dunes. Eolian deposits should not be used for road construction because these deposits are typically too wet, frost susceptible, and susceptible to erosion.

Undifferentiated: Also referred to as undifferentiated mosaic, these materials consist of a mixture of alluvial, colluvial, glacial, and eolian sediments including clays, silts, sands, and gravels. The materials will be highly variable and likely covered by ice-rich organic silt with localized areas of peat. Bogs and ponds will be numerous. Glacial features such as kettles, kames, and eskers will be present. Most of the material will likely not be suitable for use in construction.

Bedrock: Bedrock exposures will be encountered on each of the routes. Several types of bedrock make good sources of roadbed material and riprap. These include greenstone, conglomerate, dolomite, chert, and limestone. However, limestone and dolomite can be sensitive to chemical and solution weathering. The greenstone bedrock is typically massive, has high strength, is resistant, and quarried material could be used for road construction. Generally, conglomerate, mudstone, phyllite, shale, and sandstone can degrade over time and are not ideal materials for road construction. Some areas of volcanic and intrusive rocks may be encountered along the routes. These rocks are generally composed of, schist, quartzite, gneiss, slate, and graywacke. This material should be suitable for road construction although schist and gneiss tend to breakdown easily into silt and clay sized particles.

The ability to use any of these rock types will also depend on the amount of weathering, degree of metamorphism, and rock quality. A high strength rock type may not be suitable for use if highly weathered and fractured while a low strength rock that has been subjected to some metamorphism may be suitable for use as aggregate.

OVERLAND CORRIDORS

There are two overland corridors proposed for road routes. The routes extend from Council to the Dalton and Elliot Highways and are shown in overview on Figure H1 and in greater detail on Figures H2 through H5. A brief description of the general geologic conditions based on physiographic divisions (Wahrhafitg, 1965) is provided below and shown on Figure H6. In addition to variable geologic conditions, both routes are located within the permafrost zone (Figure H7); underlain by moderately thick to thin permafrost in areas of fine-grained deposits (lacustrine, eolian). Some discontinuous or isolated masses of permafrost may be encountered in areas of course-grained deposits (alluvial, fluvial).

1) Route 1 (Council to Bettles to Dalton Highway)

A. Seward Peninsula (Council) to Koyuk River/community of Haycock Area

The route heads west across the alluvial and moraine deposits of the Seward Peninsula through the Bendleben and Darby Mountain ranges to Koyuk River area. The Bendleben and Darby Mountains are primarily composed of Paleozoic schist and gneiss cut by granitic intrusions.

B. Koyuk River/community of Haycock to the Lockwood Hills subprovince

From the undifferentiated deposits of the Koyuk River area, the route crosses the Buckland River Lowland and extends through the Lockwood Hills subprovince via the Pah River valley subprovince. The Buckland River Lowland subprovince contains alluvial deposits and the Pah River valley contains moraine and drift deposits. The mountains of the Lockwood Hills subprovince are composed of graywacke, sandstone, shale, siltstone, and conglomerate.

The area between the Pah River and Allakaket/Alatna follows the base of the Lockwood hills and contains areas of alluvial, glacial moraine, and undifferentiated deposits.

Slope stability may be an issue within the Pah River valley.

C. Lockwood Hills subprovince to the community of Bettles

This section of road travels through the Kanuti Flats. The route traverses near low, irregular hills and through the forest-covered meander belts of the Koyukuk and Kanuti Rivers. The regional geology consists of alluvial and glaciofluvial deposits.

D. The community of Bettles to the Dalton Highway

Once the route reaches the John River, it veers south toward the community of Bettles. Bettles is located at the confluence of four major rivers (John River, Wild River, South Fork Koyukuk, and Middle Fork Koyukuk). Between Bettles and the Dalton Highway, the route traverses through the Kokrine-Hodzana Highlands subprovince, crossing the South Fork Koyukuk River. The segment from Bettles to the Dalton Highway crosses over areas of alluvial and glaciofluvial deposits interspersed with glacial moraine and drift deposits.

2) Route 2b (Council to Manley Hot Springs)

A. Community of Council to community of Koyuk

The proposed route extends west across the alluvial and moraine deposits of the Seward Peninsula through the Bendleben and Darby Mountain ranges to Koyuk River area. The Bendleben and Darby Mountains are primarily composed of Paleozoic schist and gneiss cut by granitic intrusions.

B. Community of Koyuk to the community of Koyukuk

From the community of Koyuk, the route crosses the Buckland River Lowland and extends through the Nulato Hills. The Buckland River Lowland contains alluvial deposits while the Nulato Hills consist of graywacke, sandstone, shale, siltstone, and conglomerate bedrock.

C. Community of Koyukuk to the community of Galena

Upon reaching the community of Koyukuk what the alignment crosses the Koyukuk Flats to Galena. The Koyukuk Flats, near the confluence of the Yukon and Koyukuk Rivers, are comprised of fluvial and eolian silt deposits

D. Community of Galena to the community Tanana

Between Galena and Tanana, the route traverses through the Kokrine-Hodzana Highlands subprovince along the Yukon River. This segment of the route crosses over areas of alluvial and glaciofluvial deposits interspersed with glacial moraine and drift deposits. The Kokrine Hills are generally underlain by Paleozoic schist and gneiss having a northeast trending structural grain, cut by several granitic intrusions.

E. Tanana to Manley Hot Springs/Elliot Highway

Upon reaching Tanana, the alignment follows along the Yukon River within the Yukon-Tanana Uplands subprovince. The Yukon-Tanana Uplands are primarily comprised of alluvial deposits with windborne silts on the lower slopes of hills and thick accumulations of muck overlying deep stream gravels in the valleys.

CONCLUSIONS

1) Road construction in this area of Alaska, regardless of the alignment, will more than likely have to contend with frozen soil conditions. Frozen soils tend to consist of either thaw stable or thaw unstable soils. Thaw stable soils will not settle substantially upon thawing (gravels with low ice content). Thaw unstable soils will settle substantially upon thawing.

   Many roads in remote locations containing permafrost are constructed by clearing the trees and shrubs, but leaving the organic mat to help preserve the permafrost. Geotextile is placed on the ground surface and fill material, preferably gravel, is placed on top in lifts. The thickness of the roadbed material is a function of the anticipated loading and what is necessary to limit permafrost degradation. Roadside slopes also tend to be flatter in a permafrost environment. In sensitive areas, insulation may also be used, although this can be expensive over long distances. Excavation does not typically occur except in material sites. The method of construction will vary depending on the material and conditions encountered and generally require annual maintenance.

2) Permitting will be a significant obstacle. Quarrying and mining of materials will be subject to scrutiny by federal, state, and local entities. Excavation from within active river/stream channels may be difficult, especially if anadromous. A challenge will be to locate material sites close to the alignment, limiting haul distances.

3) Roads constructed near active stream channels may be subject to erosion over time as streams meander. Flooding will also be a concern. Roads constructed at the base of hills or on slopes may have to address slope stability and mass wasting issues.

REFERENCES

Selkregg, L.L., 1974, *Alaska Regional Profiles*, Vol. 5, University of Alaska, Arctic Environmental Information and Data Center, Anchorage, Alaska, 265 p.

Selkregg, L.L., 1974, *Alaska Regional Profiles*, Vol. 6, University of Alaska, Arctic Environmental Information and Data Center, Anchorage, Alaska, 346 p.

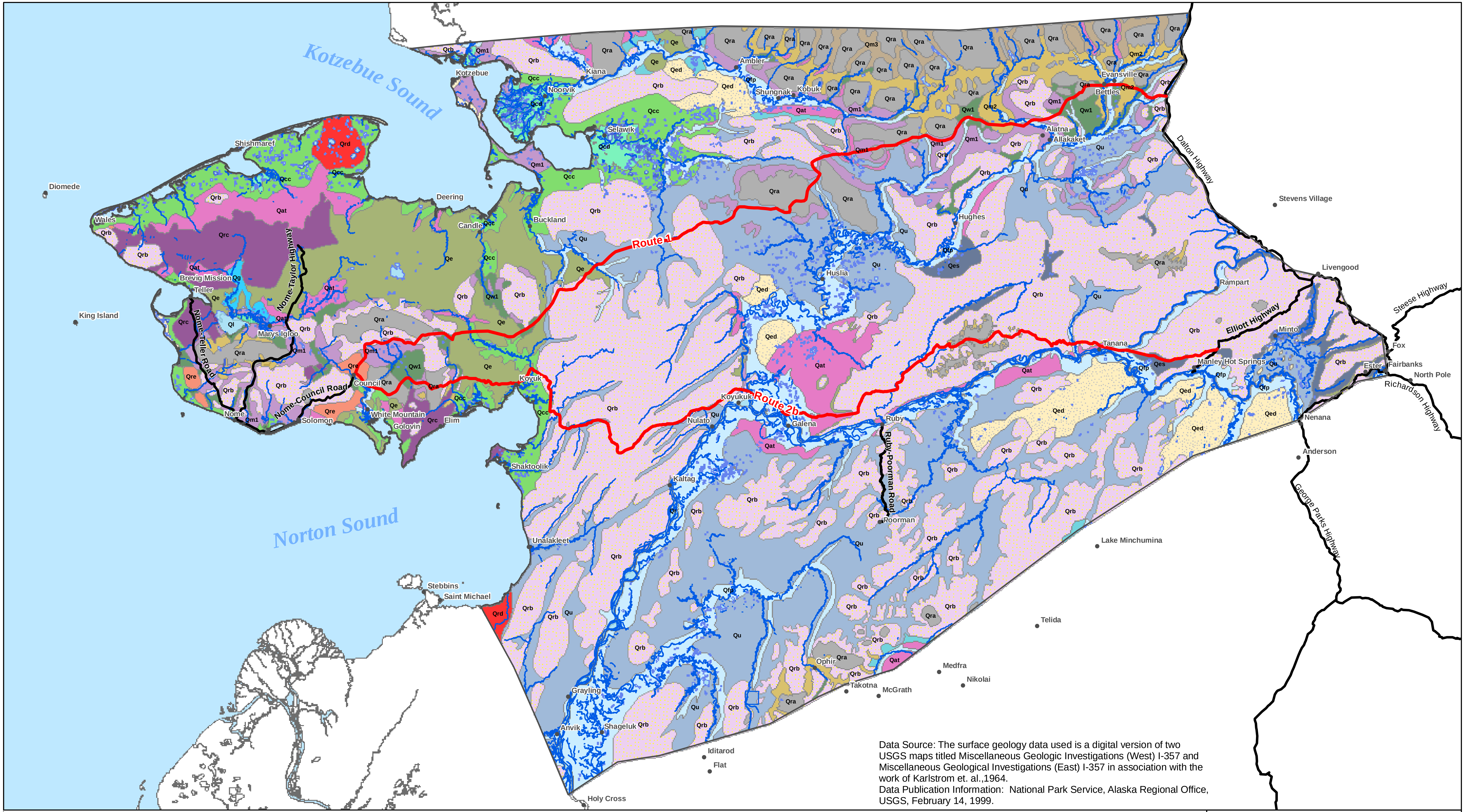
Wahrhaftig, Clyde, 1965, *Physiographic Divisions of Alaska*, US Geological Survey Professional Paper 482, US Government Printing Office, Washington D.C., 52p., 6 plates.

USGS, 1999, State Surficial Geology Map of Alaska

Attachment: Figures H1 through H7

D60060.Middendorf.KN.MEK.120409.mas

FIGURES



Data Source: The surface geology data used is a digital version of two USGS maps titled Miscellaneous Geologic Investigations (West) I-357 and Miscellaneous Geological Investigations (East) I-357 in association with the work of Karlstrom et. al.,1964.
Data Publication Information: National Park Service, Alaska Regional Office, USGS, February 14, 1999.

- ALLUVIAL FAN
- ALLUVIAL TERRACE
- ALLUVIUM OVER OLD ALLUVIUM
- BEACH
- BEDROCK & COARSE RUBBLE
- COARSE & FINE RUBBLE
- COASTAL DELTA
- CURRENT GLACIAL OUTWASH
- CURRENT MORAINE
- FINE RUBBLE
- FLOODPLAIN
- GLACIER
- HIGHLY MODIFIED MORAINE
- RIVER & LAKE
- LIGHTLY MODIFIED MORAINE
- MODERATELY MODIFIED MORAINE
- OLD GLACIAL OUTWASH
- OLD MARINE & ALLUVIUM
- PRO-GLACIER LAKE OVER MORAINE
- PROGLACIAL LAKE
- SAND DUNE
- UNDIFFERENTIATED MOSAIC
- UPLAND LOESS
- VALLEY LOESS & ALLUVIUM
- VOLCANIC
- Refined Corridor Alternatives
- Existing Roads
- Rivers
- Communities

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Miles

Figure H1
Generalized Geology Map
Overview

Western Alaska Access Planning Study

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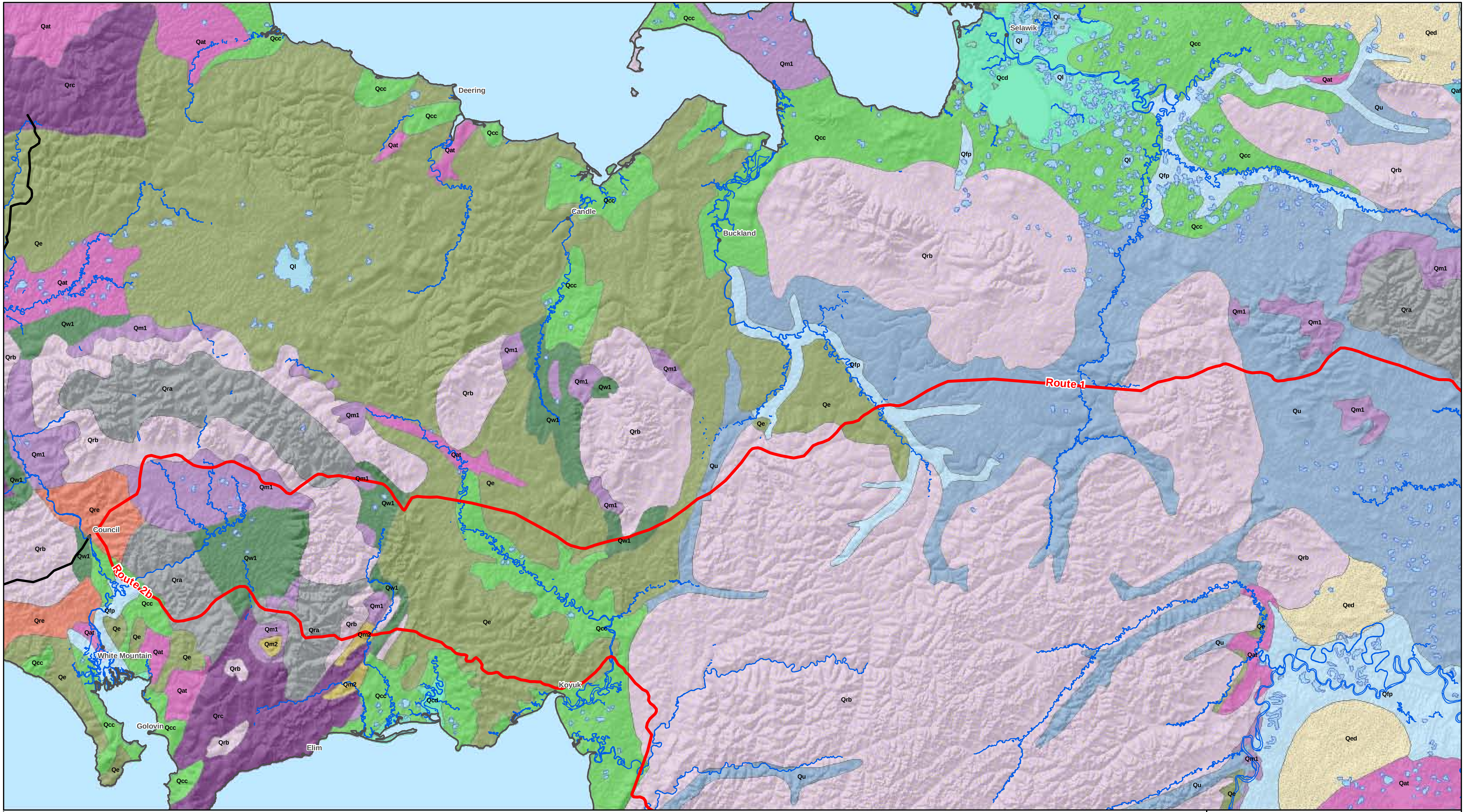

Figure H2
Generalized Geology Map

Route 1 West

Western Alaska Access
Planning Study

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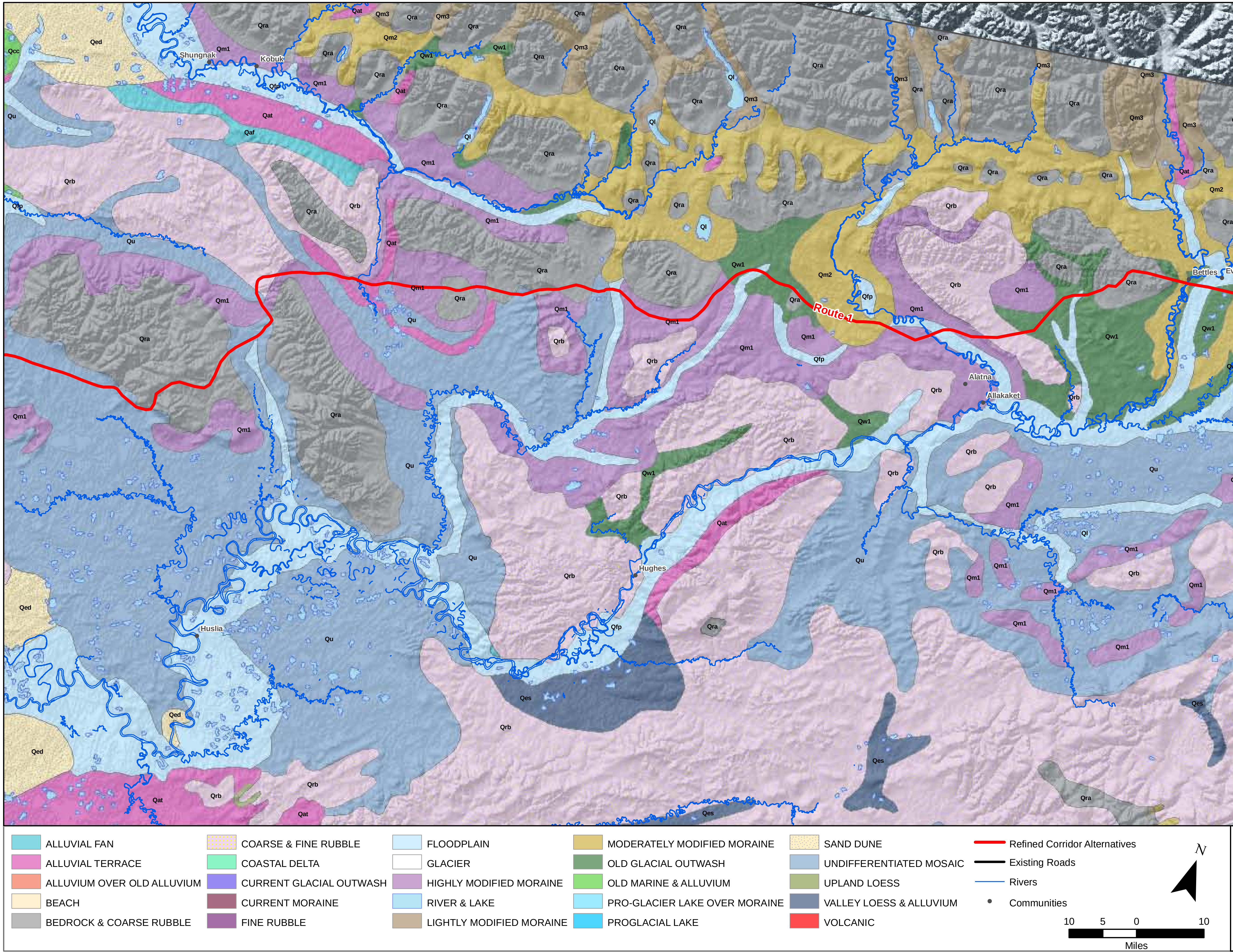

Figure H3
Generalized Geology Map

Route 1 East

Western Alaska Access Planning Study

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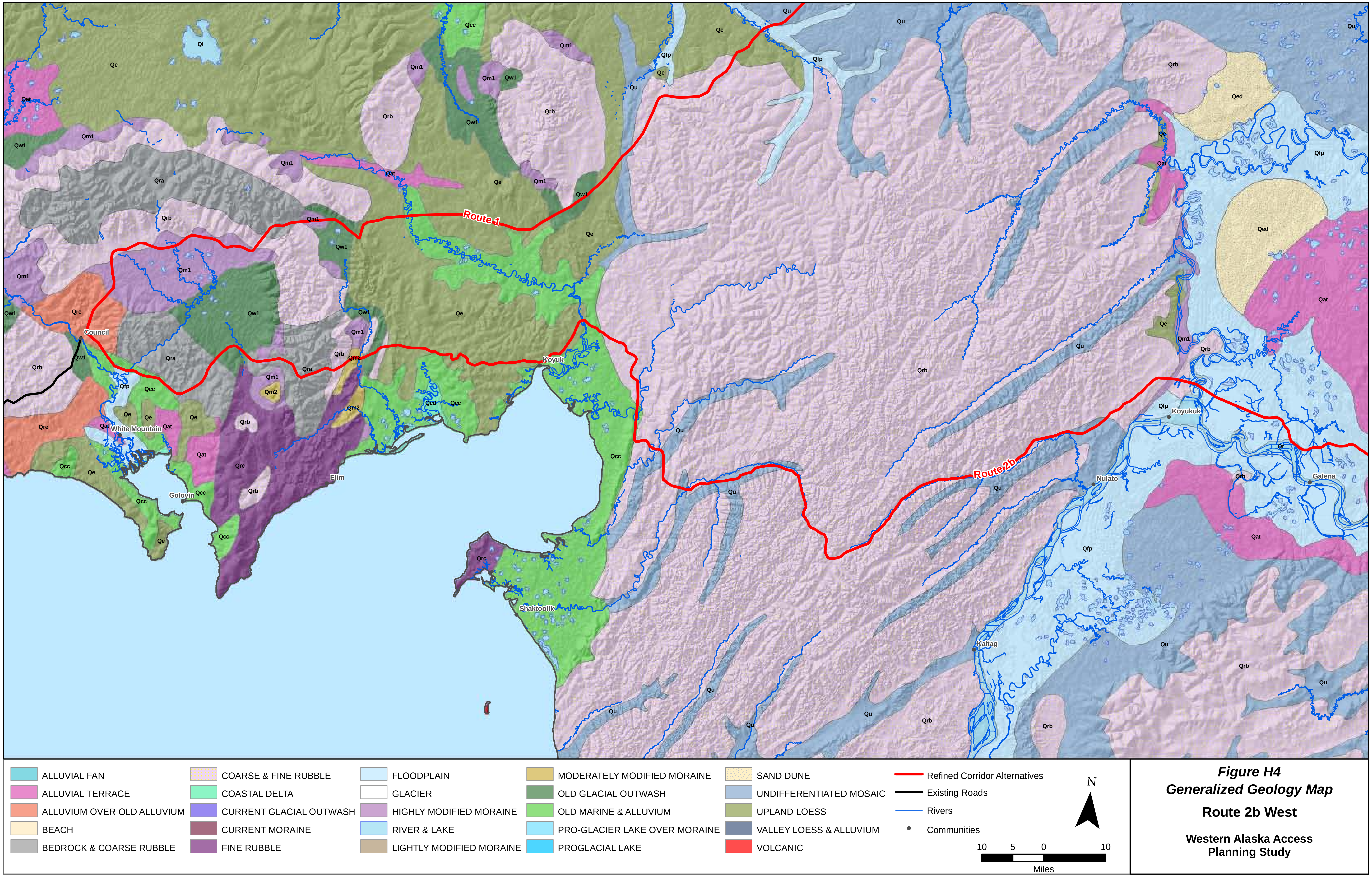

Figure H4
Generalized Geology Map

Route 2b West

Western Alaska Access Planning Study

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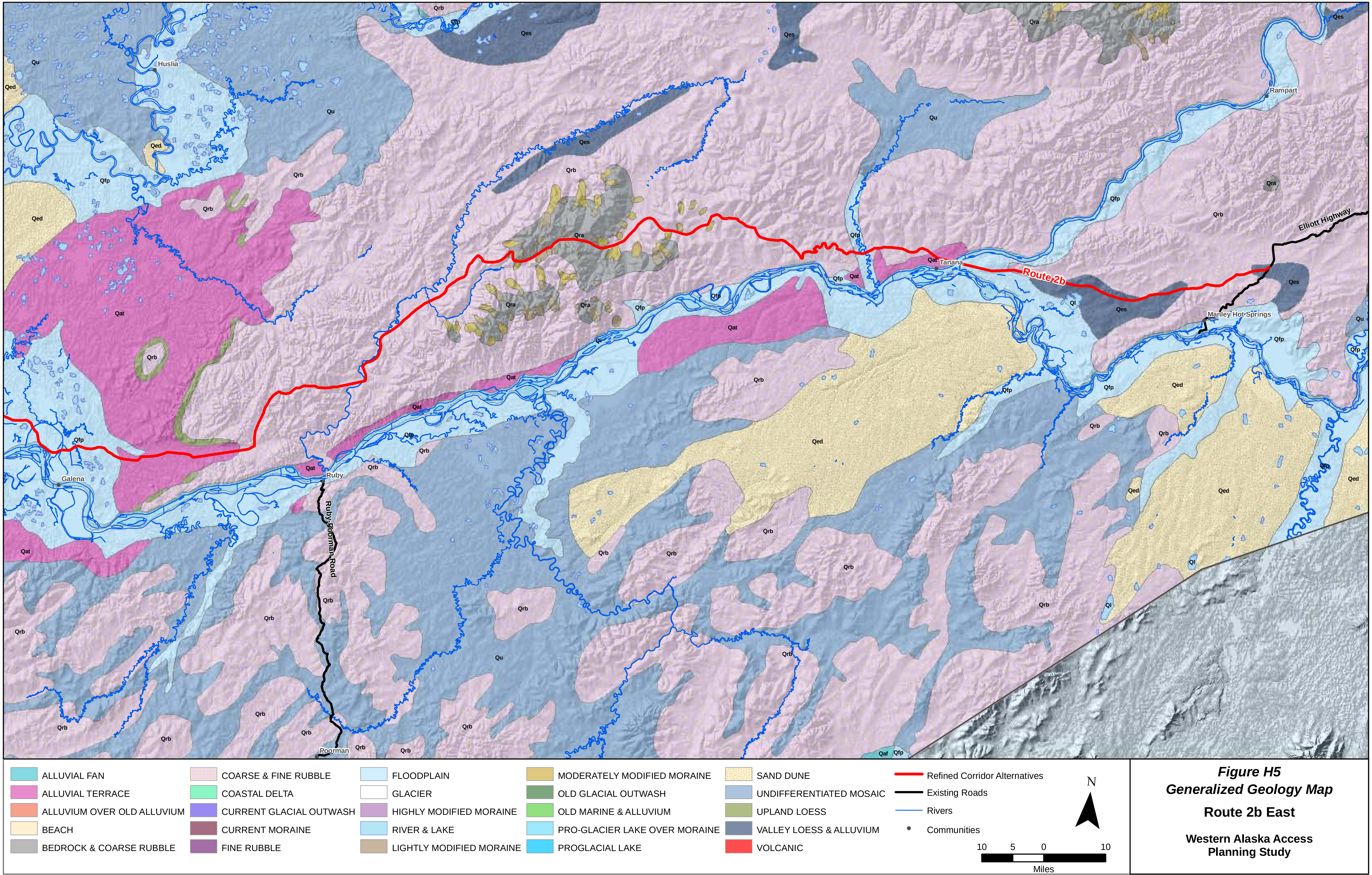

Figure H5
Generalized Geology Map

Route 2b East

Western Alaska Access
Planning Study

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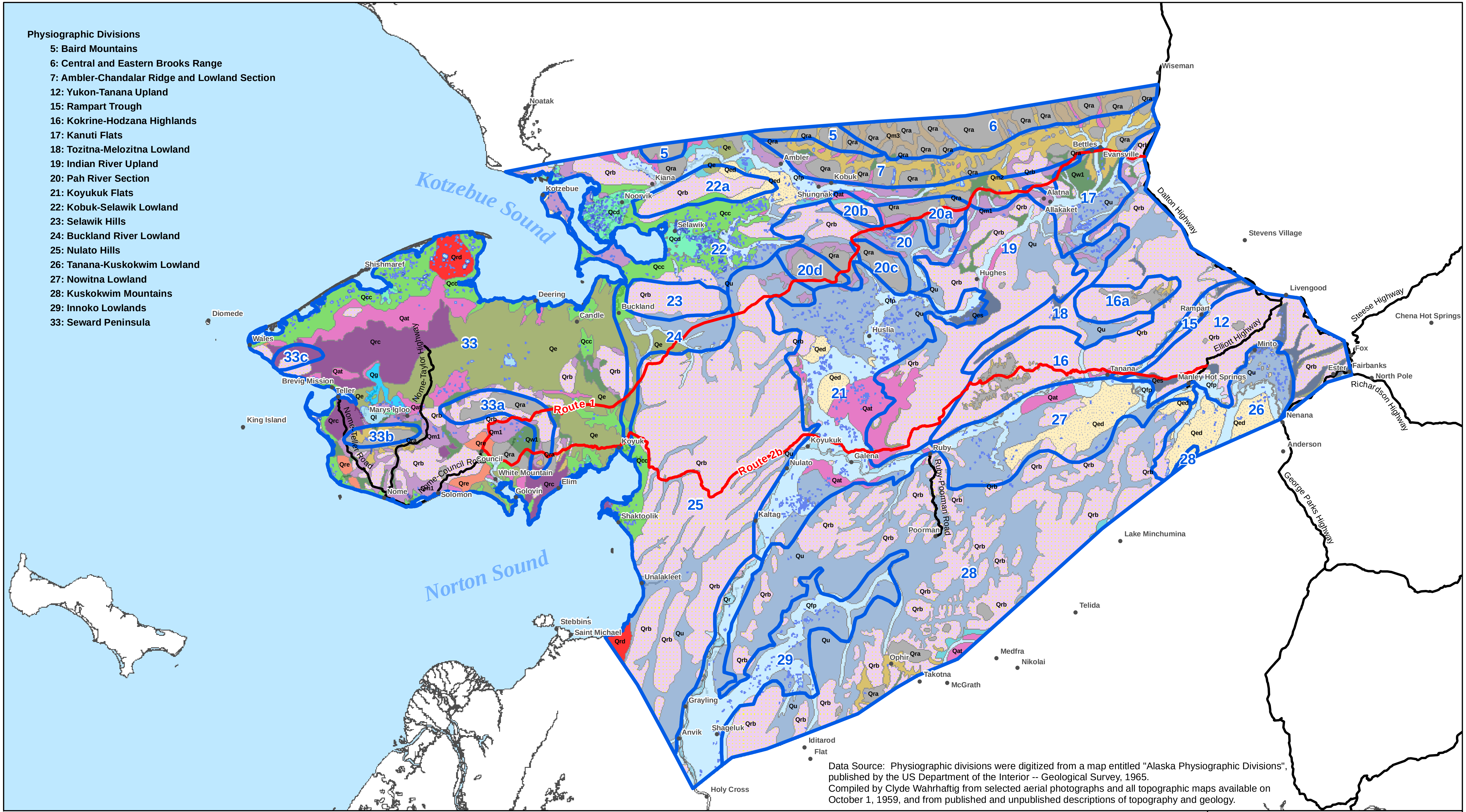

Physiographic Divisions
- 5: Baird Mountains
- 6: Central and Eastern Brooks Range
- 7: Ambler-Chandalar Ridge and Lowland Section
- 12: Yukon-Tanana Upland
- 15: Rampart Trough
- 16: Kokrine-Hodzana Highlands
- 17: Kanuti Flats
- 18: Tozitna-Melozitna Lowland
- 19: Indian River Upland
- 20: Pah River Section
- 21: Koyukuk Flats
- 22: Kobuk-Selawik Lowland
- 23: Selawik Hills
- 24: Buckland River Lowland
- 25: Nulato Hills
- 26: Tanana-Kuskokwim Lowland
- 27: Nowitna Lowland
- 28: Kuskokwim Mountains
- 29: Innoko Lowlands
- 33: Seward Peninsula

Data Source: Physiographic divisions were digitized from a map entitled "Alaska Physiographic Divisions", published by the US Department of the Interior -- Geological Survey, 1965.
Compiled by Clyde Wahrhaftig from selected aerial photographs and all topographic maps available on October 1, 1959, and from published and unpublished descriptions of topography and geology.

■ ALLUVIAL FAN
■ ALLUVIAL TERRACE
■ ALLUVIUM OVER OLD ALLUVIUM
■ BEACH
■ BEDROCK & COARSE RUBBLE
■ COARSE & FINE RUBBLE
■ COASTAL DELTA
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■ SAND DUNE
■ UNDIFFERENTIATED MOSAIC
■ UPLAND LOESS
■ VALLEY LOESS & ALLUVIUM
■ VOLCANIC

— Refined Corridor Alternatives
□ Physiographic Divisions
— Existing Roads
● Communities

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Miles

Figure H6
Physiographic Divisions

Western Alaska Access Planning Study

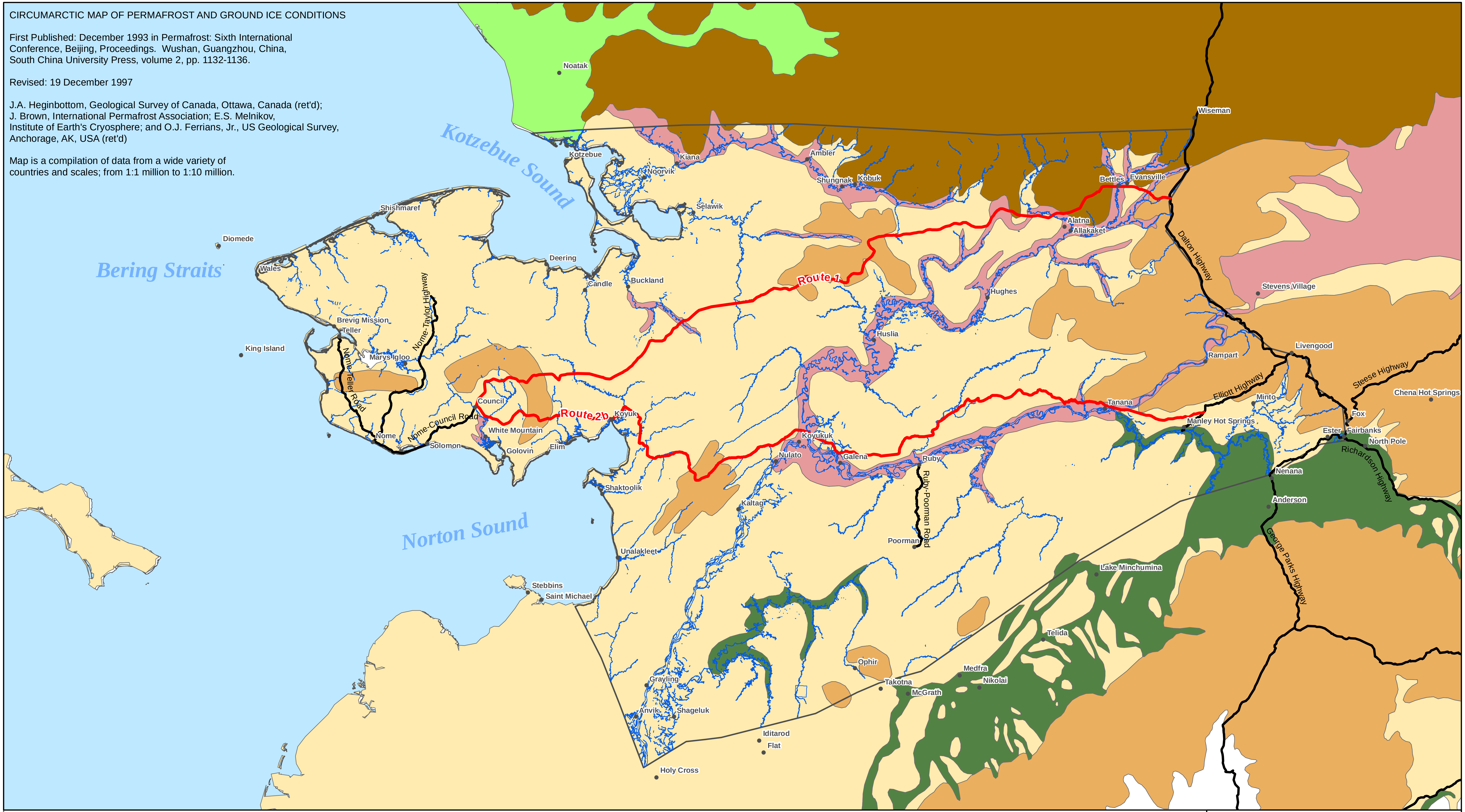
CIRCUMARCTIC MAP OF PERMAFROST AND GROUND ICE CONDITIONS

First Published: December 1993 in Permafrost: Sixth International Conference, Beijing, Proceedings. Wushan, Guangzhou, China, South China University Press, volume 2, pp. 1132-1136.

Revised: 19 December 1997

J.A. Heginbottom, Geological Survey of Canada, Ottawa, Canada (ret'd); J. Brown, International Permafrost Association; E.S. Melnikov, Institute of Earth's Cryosphere; and O.J. Ferrians, Jr., US Geological Survey, Anchorage, AK, USA (ret'd)

Map is a compilation of data from a wide variety of countries and scales; from 1:1 million to 1:10 million.



🟫 Mountainous Area underlain by continuous permafrost

🟧 Mountainous Area underlain by discontinuous permafrost

🟩 Lowland and Upland Area underlain by thick permafrost

🟨 Lowland and Upland Area underlain by moderately thick to thin permafrost

🟥 Lowland and Upland Area underlain by discontinuous permafrost

🟩 Lowland and Upland Area underlain by numerous isolated masses of permafrost

— Refined Corridor Alternatives

— Existing Roads

— Rivers

• Communities

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Miles

Figure H7
General Permafrost Conditions

Western Alaska Access Planning Study

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